

# **A COMPUTERIZED BUCKING TRAINER FOR OPTIMALLY BUCKING HARDWOODS**

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## **INTRODUCTION**

The bucking of hardwood stems constitutes the initial manufacturing decision for hardwood lumber production. Each bucking cut creates a log of fixed grade and scale. The grade and scale of each log created by the bucking determines the quantity and quality of potential lumber, which determines the value of the log within a given market. As a result, bucking decisions significantly influence the profitability of the harvesting enterprise and ultimately the efficiency of hardwood resource utilization. Poor choices of bucking cut locations with respect to the log shape, size and defect pattern irreversibly reduce value, profit and efficiency. Within a holistic discussion on felling and bucking hardwoods, F.J. Petro (1975) addresses bucking techniques which may be implemented in order to improve log value and operation profitability. In several chapters, he details the practices of jump butting and jump cutting, defect identification, manufacturing to reduce sweep and crook, and bucking for grade. Through the application of these techniques, optimum logs may be produced and substantial improvements in profitability may be realized.

More recently, work has been done in both the softwood and hardwood fields that investigates the optimization of stem utilization in concert with earlier log value improvement methods. For any given stem there exists one or more patterns of bucking cuts that will generate the maximum potential total value of logs for a specified market, under a specified set of grading and scaling rules. Evaluation of the entire stem in order to identify this value optimization pattern of cuts is referred to as optimal bucking or near-optimal bucking. In studies done on

softwood harvesting operations (Geerts and Twaddle 1985, Sessions et al. 1989, Twaddle and Goulding 1989) it has been shown that 5% to 26% of the potential value was, at that time, being lost due to sub-optimal bucking choices. Many of the identified losses in softwood stem values have been reduced by the implementation of mill yard, mechanized and automated, bucking systems. In hardwoods, improving bucking choices may result in up to a 39% to 55% increase (depending on the historical price set used) in the value of the logs produced from high quality hardwood stems (Pickens et al. 1992). Hardwoods have a greater variation in stem form, and defect type and position more dramatically affect their values, than softwoods. Small independent logging crews, who buck the stems in the woods, more commonly perform the harvesting of hardwoods. For these reasons, the task of hardwood bucking is significantly more challenging than for softwoods, and the potential gains that may be achieved by optimal bucking are greater.

Software is available that will select the optimal bucking pattern for any given hardwood stem (Lee et al. 1989)<sup>1</sup>. This software, referred to as HW-Buck, was developed at Michigan Technological University's (MTU's) School of Forestry and Wood Products (SFWP), with assistance provided by the Michigan Small Business Development Center, the Northern Hardwoods Division of Mead Corporation, Timber Products Michigan and the Louisiana-Pacific Corporation. HW-Buck was originally written as a DOS-based program. Presently it is undergoing a rewrite into a Windows-based format. This conversion is being preformed at MTU's SFWP, with assistance being provided by the Northeastern and Southern Research Stations of the USDA Forest Service. Currently, the technological integration of HW-Buck into the hardwood production process is limited by hardware capabilities. The data collection processes available for gathering stem information are not rapid enough to keep pace with in-the-woods production demands. The development of rapid data acquisition systems for hardwood stems, such as light curtain scanners, laser scanners, ultrasound, and x-ray CT, is still technologically in the future. Tangential tomographic methods are being investigated and prototyped as potential industrial-capacity internal data collection devices (Gupta et al. 1999, Schmoldt et al. 1999). Although mechanized systems will, at some future date, be available to improve value recovery by actually optimizing the bucking pattern for each stem, that technology is still under development and unavailable to harvesting operators. The equipment expenses of current versions of these technologies, for most operators in the hardwood industries, are cost prohibitive. This is especially true for small, one- or two-crew organizations.

Application of the HW-Buck software as part of a computerized bucking trainer (CBT) is the most likely near-term option for utilizing this technological development within the current hardwood production process. Through training, buckers may be equipped with the ability to determine the optimal or near-optimal bucking pattern for any given stem. In this way, the gap between technological capabilities and production applications can be efficiently and effectively reduced. Training with a CBT that incorporates optimal bucking pattern decision making offers an opportunity for the hardwood industry to substantially improve profitability while more efficiently utilizing limited hardwood resources.

## **WHAT A CBT SHOULD TEACH**

A CBT should be capable of both introducing and developing mastery of log grading and scaling, surface defect indicator identification, and near-optimal bucking pattern selection for stems of hardwood timber species. This set of skills would comprehensively equip buckers to achieve the maximum potential improvements in hardwood value recovery. The training outcomes, stated as objectives, are:

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<sup>1</sup> From [www.forestry.mtu.edu/hwbuck](http://www.forestry.mtu.edu/hwbuck)

- 1) The trainee will be able to understand and apply log grading and scaling rules;
- 2) The trainee will be able to identify significant surface defect indicators, visualize the internal implications and understand their roles in grading and scaling; and
- 3) The trainee will be able to identify the near-optimal bucking pattern for stems with varying characteristics.

Within these objectives exists a hierarchy. The ability to decide upon the correct bucking pattern for a stem requires proper grading and scaling of potential logs. In order to correctly grade and scale logs it is necessary to identify and understand the impacts of surface defect indicators.

## **WHY IMPROVEMENTS IN BUCKING ARE IMPORTANT**

Near-optimal bucking will enable the hardwood forest products industry to significantly increase recovered value of hardwood timber. Generating significant increases in the total value of the logs shipped from a harvest, with modestly increased inputs of time and manpower, will have a net positive effect on the profitability of the operation. This potential increase in profitability makes bucking improvements desirable for owners and managers of forested lands, logging operations, buyers of standing timber, and field workers who receives incentive-based wages or bonuses. Well-trained buckers are capable of making the decisions needed to improve the total value recovered from hardwood stems. When buckers are equipped with a working knowledge of how log grade (quality) and scale (volume) are determined, as well as an understanding of how stem characteristics affect grade and scale, they are capable of more closely achieving the optimal bucking pattern for each stem. This pattern produces a greater proportion of higher quality logs and recovers more timber volume for a given harvest than do patterns chosen in the field by buckers using traditional heuristics (Pickens et al. 1992). Due to the proportionally greater prices received for higher quality logs, value recovery from each stem as well as total profit can be markedly increased solely through improved bucking.

Those associated with the field of hardwood forestry are faced with the challenge of applying limited resources of hardwood timber to meet the demands of an ever-increasing population. Simply by improving bucking decisions for any given harvest operation, the scaled volume of logs produced can be increased without removing any additional stems from the stand. This improvement in scale created by optimal bucking is generated by a reduction in sweep of the products produced and occurs in spite of the fact that more cull sections are left in the woods to be decomposed and reassimilated. The challenge is to do more with less, and profitably improving efficiency is the key. Stewardship alone gives impetus for improving bucking.

## **TRAINING IS NEEDED TO IMPROVE HARDWOOD BUCKING PERFORMANCE**

The relative complexity of hardwood log grading and scaling rules makes the task of bucking difficult. The wide distribution and variety of hardwood species, together with great variations of attributes within and between species and the intricacies of utilization, creates problems in evaluating a species' utility, or scale and grade (Rast et al. 1973). Hardwood timber grading and scaling rules are constructed with two objectives in mind. One is to meet the needs of a varied group of timber products producers for a reliable standard by which to determine utility of individual logs with respect to the different products that each may produce. The second is to create a set of rules and procedures that can be quickly and accurately applied. Unfortunately for the bucker in the field or log yard, hardwood timber's utility is highly variable. Stems are rarely uniform and often contain many types of internal defects that vary, with respect to the intended lumber product, in their potential to reduce log grade or scale. This makes the rules relatively complicated. The ability to correctly apply these rules is necessary for any individual to determine the optimal bucking pattern for a particular stem. Mastery of this

ability can be achieved when training is conducted with the CBT we are profiling and the opportunity for real world practice is offered.

Also unique to hardwood timber is the large influence that non-obvious internal defects have on log grades. Even those who have the responsibility of regularly grading and scaling hardwood logs often only superficially understand the internal results of surface defect indicators. These surface defect indicators of internal flaws are the least understood components of hardwood tree and log quality. Yet, location and concentration of log defects, including several defects that are inconspicuous and nearly unnoticeable, affect hardwood timber equally with size, straightness, superficial smoothness and the absence of rot and shake (Roswell et al. 1989). Because defects are significant determinants of eventual timber utility for products, recognizing them is vital to recovery of timber value. The task a buckler must accomplish in dividing a stem into logs of optimal utility (and value), by taking into account the internal defects present, is unfortunately made more difficult because most internal defects can only be identified by their correlated surface defect indicators. It is therefore essential that these indicators are recognized and the internal results are well understood. Training is necessary to accomplish this because, in the traditional job setting, a buckler will never have the opportunity to observe the resultant lumber created from each of the logs he cuts from a stem. The training tool described within this paper meets the educational requirements needed to overcome these difficulties.

## THE CURRENT VERSION OF HW-BUCK

Researchers at Michigan Technological University's School of Forestry and Wood Products have developed a computerized bucking simulator. This tool is named HW-Buck and is commonly referred to as "The Bucking Game." HW-Buck was designed to help a trainee develop heuristics (rules of thumb) to select the optimal bucking pattern for a stem (Frayer et al. 1995). The intended design of this tool was to use it in combination with traditional methods of training log buckers (Pickens et al. 1990).

Data describing one hundred and fifty hardwood stems from actual sugar maple (*Acer saccharum*), northern red oak (*Quercus rubra*), northern red maple (*Acer rubrum*) and yellow birch (*Betula papyrifera*) trees are stored as shape information in the software's database. Complete information about sizes and locations of burls, knots, seams, sweep and end defects for each stem is contained within these files. The HW-Buck software has the ability to determine the optimal bucking solution (pattern) for these logs with respect to the market that is defined. Working out the optimal bucking solutions is a time consuming process and has already been done for the default markets. The results are stored so that the optimal solutions can be viewed instantaneously when the trainee uses HW-Buck. After choosing a market and a tree to buck, the trainee is presented with a graphical image of the stem. The images of tree stems are gray-scaled representations of the actual stems, with complete defect information presented as magenta lines and ellipses of various sizes. By using the numeric pad on the keyboard, the log may be rotated to view all sides and then bucked at any desired location. If, while in the process of bucking the stem, the trainee decides that one of his previous cuts is improperly placed, he may remove it. Once the trainee feels that a nearly optimal set of cuts has been achieved, the results of his bucking choices are then compared to the stored optimal bucking pattern. The results displayed, both for the trainee's choice and the optimal pattern, contain information about the individual logs and the value recovered from the entire stem. Length, grade, small-end diameter, sweep, percent volume deduction due to sweep, total cull, scale volume, and value are given for each log created. The total dollar value that the trainee produced from the stem is given, as well as the total dollar value that could have been achieved by selecting the optimal bucking pattern. After viewing the results, the trainee can re-buck the stem, select a new stem, or exit the game. The current version of the software allows limited personalization. Specifically, the user can define veneer grading rules and fix product prices to create new virtual markets.

## **DESCRIPTION OF A CBT**

### **The Grading and Scaling Trainer**

According to information processing theory, learning results from an interaction between an environmental stimulus and a learner (Biehler and Snowman 1993). It is undeniable that the vast majority of people are predominantly visually oriented. Our eyes are used in almost everything we do, from our jobs, to social interactions, to recreation. Visual stimulation, for the most part, is the environmental stimulus that people are most attentive and receptive to. The old saying that a picture is worth a thousand words has literal application for a CBT. This is especially true since the nature of bucking itself is a visually intensive task. Buckers must visually assess every stem and the defects on them. They must then be able to envision the potential logs that may be produced. Training for this task should be visual in its methods of communication. It should incorporate pictures and diagrams of the logs and defects as often as possible, and learners should be given the opportunity to examine and analyze these visual images. Each component of a CBT should attempt to achieve the training objective for which it was designed by visually interacting with and stimulating the learner.

The first training objective for a CBT is that the trainee will be able to understand and apply log grading and scaling rules. In order for this objective to be satisfied (as well as the others), and once the concepts have been introduced, cognitive retention (learning) and mastery should be developed through repetitious application. The trainee should be introduced to the grading and scaling rules. For trainees who have no background with the rules, the Grading and Scaling Trainer will equip them with the vital skills and knowledge needed to grade and scale hardwood logs. This trainer should display the rules, explain application of the rules and quiz the trainee on the rules. A grading and scaling game should also be included, in which the trainee will experience simulated logs (the same ones found in the Optimal Bucking Trainer) as well as realistic looking virtual logs. Further mastery of the rules will be provided during bucking simulation. The retention and mastery development process should then proceed through continued repetition. Additionally the scaling and grading rules used should be easily queried throughout the training session. So equipped, the trainee will be able to develop the ability to apply these rules correctly through repeatedly making decisions about the scale and grade of graphical logs and then viewing the actual results.

HW-Buck does not presently have a Grading and Scaling Trainer. For those who have a basic understanding of the rules, HW-Buck helps develop mastery through repetitive application. When trainees use HW-Buck, they are not asked to read a list of rules and then regurgitate an explanation of how the rules affect bucking. Instead, the trainees attempt to buck a stem using their knowledge about grading and scaling and then examine the results before attempting again.

### **The Surface and Defect Identification Trainer**

The second training objective for a CBT is that the trainee will be able to identify significant surface defect indicators, visualize the internal implications and understand their roles in grading and scaling. This can be complicated for hardwoods due to the fact that some indicators affect grade, some affect scale, and some only matter for specific purposes. To teach trainees to recognize surface defect indicators, a Surface and Defect Identification Trainer must provide high quality photographs of actual samples. For study purposes these photographs should be organized in a graphics database. This database should also contain pictures of the underlying defects taken at incremental depths within the log. Only by seeing the internal results of what is commonly seen on the surface of stems will the buckers gain an understanding of why some defects are degradations and others are not. This database, combined with a display interface, would comprise the Surface and Defect Identification Trainer component of a CBT.

Currently HW-Buck does not train buckers to visually identify surface defect indicators. The graphic representations of defects on the archived stems are drawn only to convey the relative size and position of a defect. Actual pictorial representations of each defect on a computerized log image would be too small to contain any informative visual detail. Development of the database and interface described above is being pursued. The high quality images needed to create the defect identification database are currently in the process of being compiled. These images need to be compatible with digital manipulation and display, as well as contain enough visual resolution to be distinguishable. Seventeen logs have been partitioned and photographed at depth intervals of one inch. The development of select target defects within these logs has also been more closely documented. Research using CT scanning and photos of external defect indicators being done by our USDA Forest Service cooperators in Blacksburg, VA will also be used in the Surface and Defect Identification Trainer. Just as correctly identifying surface defect indicators in the field is a challenge, displaying them on a space-limited medium for educational purposes poses an equally difficult challenge. Recent improvements in digital image acquisition capabilities have made this task more feasible.

### **The Optimal Bucking Trainer**

The third training objective for a CBT is that the trainee will be able to identify the near-optimal bucking pattern for stems with varying characteristics. This can only be accomplished through repeated attempts at identifying optimal solutions. By repeatedly bucking graphical representations of logs (complete with symbolic representations of defects) and then comparing the results to optimal patterns, trainees will eventually master the decision-making processes. The Optimal Bucking Trainer provides the opportunity to gain this experience. The end result should be the personal development of heuristics that can be used to select the near-optimal bucking pattern for actual stems.

HW-Buck does contain the simulation needed to develop this skill. The interactive graphic display allows for bucking of a realistic representation of a hardwood stem. A comparison of the bucking choices made and the results obtainable by choosing the optimal bucking pattern is available. After studying this comparison, the trainee can make adjustments to the chosen bucking pattern or attempt to optimally buck another stem.

Regardless of what a computerized trainer is teaching, ease of use and functional availability are necessary if the tool is to be usable by the majority of those who would benefit from it. In order to satisfy this requirement, the software platform must be widespread and familiar to many potential users. HW-Buck is a DOS based software system that is presently under conversion to a Windows-based platform. The Windows environment will provide a uniform, visual environment with which most computer users are familiar and comfortable. During this software conversion process, the capabilities of HW-Buck are being expanded. The ability to alter sawlog grading rules, include additional log scaling rules, and define additional roundwood products are major enhancements being incorporated into the Windows version of the model.

### **CONCLUSIONS**

Substantial gains in hardwood utilization and log manufacturing profitability are possible through improvements in bucking practices. Well-trained buckers can realistically determine near-optimal bucking patterns on stems. A CBT based on the optimization capabilities of HW-Buck offers an efficient mechanism for providing the needed training.

The current version of HW-Buck is not independently capable of achieving all three of the training outcomes that a CBT should. Although the current version does have considerable value for bucking training purposes, it is not designed to directly address the learning of grading rules and surface defect indicator identification. The

improvements needed in the training functions of HW-Buck have been identified and some modifications to the software are being initiated at MTU.

The present conversion of HW-Buck and the development of a comprehensive CBT are necessary steps in making optimal bucking training widely available. Intensive training with hardwood harvesting crews is being planned for this summer (2000) through a partnership between the Northeastern Forest Research Station of the USDA Forest Service, Menomonee Tribal Enterprises of Wisconsin, and MTU. A training system will be implemented which utilizes presentations by technicians about defect identification and implications, grading and scaling, and the current version of HW-Buck, in combination with field application of bucking. These sessions will be partially administered by staff from MTU. This training project will provide optimal bucking training, measure stem value recovery improvement and learning retention, improve estimates of potential gains through optimal bucking, and expand the HW-Buck software's database of trees. Because a fully functioning CBT is not available at this time, the training will be specialist intensive. Once the training method has been refined and a complete CBT becomes available, groups within the forest products industry will be able to independently provide the training needed to realize the potential hardwood value recovery improvements. Such a tool offers a realistic method of applying the technological advances of hardwood research within the actual production systems of hardwood manufacturing.

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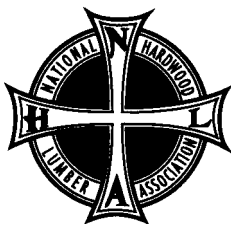


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